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The Contribution of the National Laboratories in Meeting U.S. 21st Century Challenges

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THE CONTRIBUTION OF THE NATIONAL LABORATORIES IN MEETING U.S. 21st CENTURY CHALLENGES

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Panel #1 - "Federal Investment and Resource Allocation in Science and Technology"

Two pivotal National Academies reports—*Making the Nation Safer* and *Rising Above the Gathering Storm, Energizing and Employing America for a Brighter Economic Future (RAGS)*—together with *The National Quadrennial Defense Review, The Department of Defense Strategic R&D Plan,* the report of the Intergovernmental Panel on Climate Change, and the National Academy of Engineering's Grand Challenges delineate the major challenges we face as a nation in the 21st century. They assert that fundamental advances and a sustained effort in science, engineering, and technology are needed to address these challenges effectively. Below is a partial listing of some 21st century challenges for which transformational R&D is needed:

National Security

1. Deterrence of, mitigation of, and recovery after a catastrophic nuclear—or other Weapon of Mass Destruction—event.
2. Securing the homeland against terrorist or disruptive technical (cyber, biological, directed energy, space…) or economic attacks.
3. Nonproliferation, remote radiation sensing and monitoring, port monitoring—as there is a global resurgence of nuclear power plant construction.
4. Defense of American interests against rogue states and asymmetric threats.

Energy—Environment—Health Security

1. Energy-efficiency, carbon-management/sequestration, and emissions-monitoring technologies.
2. New sustainable, affordable, low-carbon energy technologies and alternative fuels to replace those derived from coal and oil.
3. Stewardship of the Earth's climate system—providing a predictive understanding at a regional level with quantifiable margins of uncertainty to enlighten strategies

for mitigation of and adaptation to climate disruptions and to aid in forecasting the effects of and recovering from natural disasters.
4. Sustaining and enhancing the global supply of clean water and food.
5. Affordable health care for all Americans in view of an aging population and increasing probability of pandemics due to global spread of infectious disease.

Economic Security

RAGS identifies major challenges that the nation faces in the global economic competition of the 21st century: the U.S. is falling more and more behind in maintaining scientific leadership, innovation, high tech industries, and a world-leading R&D workforce. In addition, the nation's international trade deficits continue to increase as high tech industry is moving abroad. In order to reverse these trends, the U.S. must have:

1. A general public that is educated in science, technology, and math.
2. A balanced, strategic federal research portfolio to sustain the flow of new ideas that fuel the economy, provide security, and enhance the quality of life.
3. A highly attractive setting for higher education so that we can recruit, develop, and retain the best graduate students, scientists, and engineers from the U.S. and around the world.
4. Competitive incentives for on-shore innovation in high tech industry, such as tax credits for R&D, to provide high paying jobs.

These challenges to national security, energy–environment–health security, and economic security are overlapping and are inseparable from one another. They require a sustained and balanced federal R&D strategy to address, and unfortunately, they need to be addressed simultaneously. Success in each area depends on technical advances and strength in the others. All require a healthy and strategically-focused U.S. science and engineering establishment—consisting of universities, industry, and national labs—that actively engages in open scientific exchanges and provides leadership in the global science and engineering community.

Addressing many of these 21st century challenges falls squarely into the traditional R&D portfolio of the Department of Energy (DOE), which includes nuclear defense, nonproliferation, energy, environmental clean up, and science missions. While some of DOE's research funding flows to U.S. universities, the DOE national labs are essential players and conduct much of the work. In particular, the national labs provide the required security environment for national-security R&D and their multidisciplinary expertise is important for addressing environmental security challenges. Along with academia, the DOE labs are also active in scientific discovery and innovation to help

U.S. industrial competitiveness, especially as the major industrial R&D labs have abandoned their fundamental research efforts in physical sciences and engineering. In addition, the DOE labs are well positioned to work with the public and private sector on reengineering the health system and to provide research and learning opportunities for teachers and students to further U.S. science and engineering workforce development.

The seventeen DOE national labs comprise a system, unique in the world, which was created and is supported by the federal government to carry out essential national scientific and technical functions of a scale and/or with security restrictions that make them unsuitable for a purely academia environment. Further, these activities require R&D over long timescales with products important to the nation but ill-matched to more immediate business interests of much of U.S. industry. Partnerships with universities and industry, however, are vital to the success of R&D at the national labs and such collaborations in projects have been the norm from the very beginning.

The national lab system was born with the creation of the Manhattan Project during World War II. To address a critical national need—to win the race with Nazi Germany to develop the atomic bomb—required large teams of the best scientists and engineers working together in a secure environment to pursue the underlying fundamental science and design and construct the weapons. Several locations around the country, some close to universities and others very remote for security and public safety reasons, were set up as interdependent Federally Funded Research and Development Centers (FFRDCs) that were Government-Owned/Contractor Operated (GOCO). This approach allowed for maximum flexibility in the management of the science and engineering and for the recruitment of the nation's top scientists and engineers.

After the success of the Manhattan Project and the end of World War II, Congress created the Atomic Energy Commission (AEC) to direct the design and development of nuclear weapons as well as civilian nuclear energy research. This action reinforced the U.S. tradition of civilian control of the military and recognized the need for continuing federal investment in R&D. The AEC national labs continued to be managed as GOCO FFRDCs. This partnership approach was deemed to be essential for creating the special work environment required to attract the best and brightest—responsive to national needs but freed from many bureaucratic burdens and buffered from politics.

As the Cold War evolved (and the AEC became ERDA and then DOE), the mission of the system of national labs has evolved as well—always focusing on long-term U.S. government needs with substantial scientific and technological content, often with complex security, safety, project management, and other operational challenges. Major innovations were needed during the during the Cold War to improve the performance, safety, security of the nation's nuclear stockpile and deter Soviet aggression. In addition, Eisenhower's "Atoms for Peace" initiative furthered interest in civilian nuclear power. Accordingly, R&D at the national labs centered on nuclear energy and waste processing, nonproliferation of nuclear materials worldwide, understanding of weapons effects and detection of remote nuclear tests, advancement of micromechanical systems and radiation-hardened electronics for diagnostics and weapon systems, and environmental cleanup of the nuclear sites. Many "spinoffs" arose, such as the launch of the Human Genome Project from work on the effects of ionizing radiation on biological systems and the development of global atmospheric circulation models (climate models) to track of the fallout from atmospheric nuclear tests.

The national labs developed and continue to shoulder a special responsibility in pursuit of fundamental science. Their mission is to develop the new scientific tools required to make major scientific breakthroughs. These are often big science projects—using teams of scientists and engineers to design and build large particle accelerators, synchrotron light sources, thermal reactors and spallation sources for neutron scattering, x-ray lasers, the first genome sequencing institute, large magnetically confined plasma machines for studying the science and engineering challenges for magnetic fusion energy, and the world's largest lasers for inertial confined fusion energy. The DOE labs now operate a system of major scientific research user facilities that is of broad benefit to the academic community, accessible free of charge by any nonprofit researcher whose proposal is accepted by rigorous peer review.

The national labs also provide leadership in scientific computing. The end of nuclear testing in the early 1990's brought about the start of the science-based stockpile stewardship program, in which the labs needed to greatly enhance their non-nuclear experimental facilities and their simulation capabilities. In partnership with U.S. industry, the labs undertook a 10 year quest for a million-fold enhancement of scientific computation and simulation capabilities at dramatically reduced cost per flop. Achieving (and now greatly surpassing) that goal has created a world-leading U.S. commercial capability and an unprecedented ability to simulate real materials at scale. This world-class capability, essential for the success of stockpile stewardship without nuclear testing, is creating a revolution in the design of sophisticated industrial material parts by other industrial sectors—such as tires—as well as simulation drug targets for the pharmaceutical industry. A similarly demanding R&D effort in hardware, software, scientific modeling, validation and verification is required to create quantitative predictive models of regional climate under specified scenarios that will be needed to inform policy makers. The national labs have the expertise and experience, the ability to create strong collaborations with academia and industry, and the creative environment to provide leadership on this 20-30 year major international project.

The labs provide the essential unique expertise and personnel for round the clock 24/7 operations needed to meet national emergencies in nuclear forensics for both pre- and post- detonation nuclear events worldwide. They also provide 24/7 reachback in atmospheric plume modeling, national infrastructure survivability, bioterrorism threat analysis, and city, port and space surveillance for both DOE and other national security agencies. These operations leverage the labs' unique scientific and engineering base as well as their leadership in high performance computing and simulation.

In applied energy technologies, the labs have made advances in collaboration with industry—in such technologies as carbon sequestration, fuel cells and solar cells, as well as major strides in energy efficiency. The National Research Council concluded in an evaluation that DOE's energy efficiency and fossil energy programs from 1978 to 2000 have brought more than $30B in net energy efficiency savings and $60B in environmental benefits. Most of these savings were attributed to programs involving DOE laboratories working with industry in areas of improved energy efficiency in buildings technologies and in NOx controls for large utility boilers.

As the Administration and Congress grapple with the difficult priorities of the nation and consider the balance of the federal R&D portfolio, it is important for them to strike a strategic balance in funding among individual researchers at universities, construction and operation of "big science" user facilities (mostly at national labs) that broadly serve the research community, and large-scale multidisciplinary R&D at the national labs to work on national challenges. These important national needs may take decades to address, are not really appropriate solely for academic researchers, and are (by the nature of the problem) not profit generating. As I have stressed, these challenges need attention while the national lab infrastructure and budgets, roughly 9% of the total U.S. federal R&D spending, are eroding in line with federal spending on engineering and the physical sciences and the steady decline in defense fundamental research spending. Over the last year because of the federal budget squeeze and lack of improvement in R&D budgets (despite the COMPETES act), the national labs have laid off hundreds of scientists and engineers and thousands of support staff, have enforced rolling furloughs, and have been forced to cut back in operations at scientific user facilities.

As stated in their report, " ...the [RAGS] Committee is deeply concerned that the scientific and technological building blocks critical to our economic leadership [and national and energy security] are eroding when many other nations are gathering strength... We fear the abruptness with which a lead in science and technology can be lost..."

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